Such grand eruptions may well be expected to take place as stars cool, and if in two or more dull and comparatively cool stars such a state of things were imminent, then the tidal action due to their near approach might be amply adequate to determine, as by a trigger action, such eruptions.

Under such conditions, fluctuations of brightness and subsequent partial renewals of the eruptive disturbances might well take place.

## III. "The Process of Secretion in the Skin of the Common Eel." By E. Waymouth Reid, Professor of Physiology in University College, Dundee. Communicated by Professor M. Foster, Sec. R.S. Received April 18, 1893.

(Abstract.)

Leydig, more than forty years ago, demonstrated the possibility of a secretory process in the skins of Fish by the discovery in the epidermis of some twelve genera, of specialised cells to which the name of "schleimzellen" was given. Since then Kölliker, Max Schultze, F. E. Schulze, Foettinger, List, Leydig himself, and others have extended our knowledge of the anatomical secreting elements of the epidermis, and shown that in many instances it is extremely probable that several varieties of such structures exist. Of the several forms of glandular elements, the goblet cell is the most widely spread, and its epidermic origin and development has been most carefully investigated by F. E. Schulze and List. Considerable difference of opinion has, however, arisen regarding the function of another form of specialised epidermic cell, viz., the club cell ("kolben" of Max Schultze), which was originally described by Kölliker for *Myxine* and *Petromyzon*, though F. E. Schulze found that such cells also occurred in *Tinca*, *Leuciscus*, *Cobitis*, *Esox*, *Silurus*, and *Anguilla*, and Fritsch in *Malapterurus*. Kölliker himself, in *Myxine*, recognised the relationship of these cells to the thread cells of the mucous sacs, first clearly described by Johannes Müller. Max Schultze, however, deemed them to be of the nature of nervous end organs, possibly contractile, on account of certain appearances in polarised light recalling those of striated muscle fibre. H. Müller, F. E. Schulze, Foettinger, Leydig, and Fritsch, finding that these club cells are not constantly found in contact with the corium, as Max Schultze thought, have all inclined towards considering a secretory function probable for these structures, but have given no very definite information as to its details. Quite recently Pogojeff has again upheld Max Schultze's nerve end organ theory in the case of *Petromyzon*.

Convinced that much of the variation in description of the appearances of the secretory elements, and of the club cells in particular, had arisen from the fact that no special care seems to have been taken by any of the above observers to note the condition of the skin as regards secretory activity at the time of fixation for histological work, I have paid special attention to the condition of my fish, and have also resorted to artificial methods of excitation.

The Eel possesses both goblet cells and club cells in its epidermis, and is therefore suitable for the study of the process of secretion in both of these elements.

To obtain skins in the lowest phase of secretory activity, hybernating fish were obtained, rendered motionless by a successful transfixion of the medulla, and the skin immediately removed before the condition of "shock" had passed off, and therefore without any reflex movement and concomitant secretory action. Such skins are termed "normal." To obtain skins in the highest phase of secretory action, the headless or intact fish (usually caught in summer) was either exposed to the action of the vapour of chloroform, which acts at first as a powerful stimulant, subjected to faradisation, or allowed to writhe and slime in the manner common to Eels. Skins from such fish are designated "stimulated."

An examination of the *slime* of an Eel reveals the following histological elements:—

*Fibres* from 2 $\mu$ in breadth to the finest fibrils, inexcitable by electricity, indigestible by acid pepsin or alkaline trypsin, giving the xanthoproteic reaction, and staining brilliant yellow with picrocarmine. They are probably chemically of the nature of keratin. These fibres resemble in microscopic appearance those of the slime of *Myxine*, and from Eels placed in baths of pilocarpine solution are often obtained in convoluted masses.

*Granules* from 0·5 $\mu$ to 0·75 $\mu$ in diameter, soluble in 5 per cent. acetic acid, giving the xanthoproteic reaction, swelling, but not dissolving, in dilute alkali, resisting peptic and tryptic digestion, and staining red with picrocarmine.

*Nuclei* from 2 $\mu$ to 4·5 $\mu$ in diameter.

*Epidermic cells*, and occasionally extruded *goblet cells*.

In addition, mucin is present in the slime, seeing that the aqueous extract boiled for several hours with 2 per cent. sulphuric acid yields a substance capable of reducing Fehling's fluid, and is moreover precipitated by acetic acid. The acetic acid precipitate, however, being partly soluble in excess of acetic acid, and leaving an insoluble residue after digestion with pepsin and hydrochloric acid, it is probable that nucleo-albumin may also be present, though sufficient material for a phosphorus analysis was not collected.

*Histology of the Normal Epidermis.*—This has been studied by

maceration in Ranvier's "third part" alcohol and teasing, and by sections cut by the paraffin method.

*The club cells* arise from the cells of the palisade layer by amitotic division. Around the nucleus of the young cell a granular modification of the protoplasm occurs, which is the forerunner of the formation of a vesicle which always bears a distinct relation to the nucleus in its origin. The contents of the vesicle, at first homogeneous, become granular, and a lattice work of the surrounding protoplasm forms a distinct wall. In staining reaction the contents of this vesicle differ markedly from those of the goblet cells described below. They refuse to give the red-violet reaction with thionin, considered by Hoyer as characteristic of mucin, stain well with soluble blue, alone of all the dyes used, except that in sublimate specimens they take the methyl green of the Biondi stain in contradistinction to the body of the club cell which takes the acid fuchsin.

At a later stage, by a vacuolation of the material of the club cell round about the vesicle, it is set free, either as a cell with latticed wall resembling the "Leydig's cells," described by Leydig, Langerhans, Flemming, and Pfitzner in the epidermis of larval *Proteus* and *Salamander*, by List in larval *Triton*, and Carrière and Paulicki in *Siredon pisciformis*, or as a granular mass with some of the club cell body material still adherent. (Formation of the "escape cell" or "escape mass.")

The remainder of the club cell forms a spirally coiled mass ("fibre mass") staining brilliant yellow with picrocarmine.

Both "escape cell or mass" and "fibre mass" finally reach the surface of the epidermis and are extruded, the granules and nuclei of the former giving rise to the granules and nuclei of the slime, and the latter becoming further broken up to supply the fibres.

In the elimination of the elements derived from the club cells the surface epidermis is lifted, and the spiral formation of the fibre masses appears to aid in this act.

*The goblet cells* are of the "footed" variety, and arise direct from the palisade cells. They are pushed to the surface by the supply of ordinary epidermic cells originating below. The young cells, with closed theca in the lower layers, contain distinct granules in osmic vapour or Flemming's fluid material, giving the red-violet reaction with thionin and staining well with most basic dyes. There is no evidence of List's "filar and inter-filar mass," except in those cells which have nearly reached the surface, and whose contents are probably altered by imbibition. A process of regeneration of goblet cells near the surface appears to occur, for after the discharge of the first load of mucigen the protoplasmic foot remaining in the epidermis grows, and develops the red-violet thionin reaction never present in the fully developed goblet, except in the contents of the theca.

*Fibroblasts.*—Among the cells of the lower layers of the epidermis are found small cells 4 to 5 $\mu$ in diameter resembling lymphocytes, generally in little masses, and with nuclei often presenting mitotic figures. Such cells have been described by Langerhans in *Petromyzon Planeri*, List in *Cobitis*, and Fritsch in *Malapterurus*. List has described them as wandering cells passing in from the corium, and considers that they are finally extruded in degenerated form, as Stohr has demonstrated in the case of the tonsil. Fritsch saw no evidence of this extra-epidermic origin in *Malapterurus*, and came to the conclusion that these cells supply the surface epidermic scales. In the Eel these cells are undoubtedly in their origin foreign to the epidermis, and can be traced from the blood vessels of the corium through the basement membrane. In the epidermis itself all forms can be traced between the lymphocyte-like cell (fibroblast) and connective tissue cells with fine processes, which abound especially in the lower layers. Leydig has already demonstrated that connective tissue cells other than chromatophores may exist between the epidermic elements of Fish (*Cyprinus carassius*), and it is interesting to note that Langerhans, who first described these "kleine Rundzellen," was of opinion that they represented contracted chromatophore-like cells devoid of pigment. It is easy to demonstrate a complete network of connective tissue in the epidermis by sections parallel to the surface, especially in cases where the bodies of the club cells have become shrunken, and its function appears to be to hold together a tissue which, on account of the peculiar processes involved in secretion, would otherwise be of very labile nature.

The process of secretion, therefore, so far as it can be deduced from the appearances in the epidermis of slowly secreting winter Eels, appears to be as follows :—

Goblet cells, the direct descendants of palisade cells, are gradually forced to the surface by young epidermic cells derived from the same source. On nearing the surface these swell, probably by imbibition of water, and, a stoma forming in the theca, the contents are discharged, the remainder of the cell not necessarily being at once extruded, but capable of undergoing regeneration. The club cells from the same origin end in (i) a spirally wound fibre mass, which, after probably helping, by a kind of "elater" action, to remove the surface, is discharged and breaks up into the slime fibres; and in (ii) a mass of granular material inclosing the original nucleus, also discharged, and giving rise to the granules and nuclei of the slime.

*Histology of Artificially Stimulated Epidermis.*—The details of the secretory act deduced from the observation of the slowly acting skins of winter Eels are confirmed, and in some points extended, by the observation of stimulated skins.

Chloroform vapour applied to the headless or intact animal causes

such violent action that the whole epidermis is loosened. An almost "volcanic" eruption of "fibre masses" from the club cells occurs, and at the same time many new goblet cells appear in the lower layers. This result, so far as concerns the club cells, is of reflex origin, for chloroform vapour applied to the exsected skin does not produce the effect. There is, then, physiological evidence of a connexion between the club cells and the central nervous system, though I have been unable to obtain convincing proof of actual nerve fibrils by the use of gold. The surface of the epidermis may be completely thrown off by the rapid production and uncoiling of the "fibre masses" of the club cells. At the same time a rapid passage of fibroblasts into the epidermis takes place, probably with a view to affording support to the epidermic elements during the subsequent regenerative processes that must occur. This inroad of fibroblasts may be so great, and the secretory activity so violent, that, under such circumstances, whole masses may be extruded still in the elementary lymphocytic form.

The action of faradisation is less violent, but, not being followed by any narcotic action upon the elements, may be employed to obtain a picture of the result of prolonged stimulation. In such experiments the epidermis is found bereft of superficial cells, and its surface covered by a mass of extruded club cells and fibre masses, if the stimulation has been carried out in air. Dividing nuclei in both the palisade cells and ordinary epidermic cells are far more frequent than normal, and, as before, the number of fibroblasts is excessive.

By poisoning Eels with atropine a condition of the epidermis is found in which the club cells go through their metamorphosis while still in contact with the corium, the surface epidermis is intact, and the whole structure becomes thicker from the formation of epidermic cells without concomitant removal.

In conclusion, it should be noted that, by stimulating specimens of *Petromyzon fluviatilis* with chloroform vapour, evidence has also been gained of a similar production of fibres from the bodies of the club cells. The conclusions stated at the end of the communication of which the above is a short abstract are as follows:—

1. The secreting elements of the epidermis of the Common Eel consist of goblet cells and club cells, both direct descendants of the cells of the palisade layer. The former supply a mucin, the latter threads and a material appearing as fine granules in the slime.

2. The goblet cells contain mucin granules, and, after reaching the surface and discharging their load, are capable of undergoing regeneration by growth of the protoplasmic foot and re-formation of mucin.

3. The threads of the slime resemble those of *Myxine glutinosa*,

but are usually of finer texture. As in *Myxine*, they are developed from the club cells, but there are no special glandular involutions of the epidermis. The club cells of *Petromyzon fluviatilis* also supply slime threads.

4. The granular material of the slime is the contents of vesicular spaces developed in the club cells in the immediate neighbourhood of their nuclei, and is set free enclosed in a lattice work developed by vacuolation of the surrounding material, and finally extruded, carrying with it the original nucleus of the club cell.

5. The remainder of the club cell, after extrusion of its vesicle and nucleus, becomes a spirally coiled fibre, which finally breaks up into the fine fibrils of the slime.

6. Severe stimulation, especially by the vapour of chloroform applied to the intact animal, causes so sudden a development of the coiled fibres from the club cells that the surface of the epidermis is thrown off and the secretory products set free *en masse.* This process is of reflex nature, for similar excitation applied to excised skin is without effect.

7. A system of connective tissue cells, distinct from chromatophores exists in the epidermis developed from cells which are direct descendants of leucocytes, and which can be traced from the blood vessels of the corium through the basement membrane into the epidermis. The number of these wandering cells in the epidermis is greatly increased by stimulation, probably with a view to providing subsequent support to the secretory elements during regeneration.

## IV. "The Experimental Proof that the Colours of certain Lepidopterous Larvæ are largely due to modified Plant Pigments, derived from Food." By E. B. POULTON, F.R.S. Received May 12, 1893.

(Abstract.)

The object of this investigation was to afford a conclusive test as to the theory, previously submitted by the author, that some of the colours of certain Lepidopterous larvæ are made up of modified chlorophyll derived from the food-plant.

Larvæ from one batch of eggs laid by a female *Tryphæna pronuba* were divided into three lots fed (in darkness) respectively throughout their whole life upon (1) green leaves, (2) yellow etiolated leaves, and (3) white mid-ribs of cabbage. The larvæ fed upon (1) and (2) became green or brown as in nature, thus proving that etiolin, no less than chlorophyll, can form the basis of the larval ground-colour. Those fed upon (3), in which neither chlorophyll nor etiolin